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Winter species composition, diversity and abundance of macrozoobenthos in Kuwait's waters, Arabian Gulf

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Abstract

The paper describes the structure of macrozoobenthos inhabiting Kuwait's waters (northwestern Arabian Gulf). Material for the study was collected from 17 stations in December 2004. A total of 270 species of macrozoobenthos and representatives of higher taxonomic groups belonging to 10 phyla were recorded and identified. Species diversity was highest in polychaetes, gastropods, bivalved molluscs and crustaceans (83, 51, 52 and 38 species, respectively). Quantitative estimates of macrozoobenthos was studied in this geographic region for the first time. In the depth of 2–20 m the abundance of macrozoobenthos averaged 795 ind./m^2. Polychaetes, gastropods and crustaceans prevailed in the sublittoral zone. In assessing species diversity the ecological indices of Shannon-Wiener, Simpson, Pielou and Margaleff were used. The obtained results point out that in Kuwait's waters the diversity of macrozoobenthos is relatively high while the level of dominance is low. It was also found that in Kuwait Bay macrozoobenthos is less diverse than in other locations of the region.

Keywords

Macrozoobenthos, littoral and sublittoral zones

Introduction

Faunistic investigations in the Arabian Gulf began in the late 19th century; since then many researchers have paid tribute to the area. During the fishery investigations which H. Blegvad carried out for the Iranian Government in 1937–1938, G. Thorson and

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B. Loppenthin had conducted the first large-scale studies of macrozoobenthos in the Arabian Gulf. Their collections of benthic invertebrates of different groups contributed to a series of important publicatons on the taxonomy and faunistics of these groups (Stephensen 1945; Wesenberg-Lund 1949). However, these studies did not cover the northwestern waters, off Kuwait's coast. During the 1960s, a team of experts headed by D. A. Jones studied biota of the intertidal zone (Jones 1986). In his study of annelids M. B. M. Mohammad also focused on this specific zone (Mohammad 1970, 1971, 1973, 1980). Knowledge of the distribution of macrozoobenthos in the sublittoral zone of Kuwait's waters in the northwestern Gulf is needed due to the lack of scientific documentation about the diversity and the quantitative distribution of bottom fauna. A couple of studies were conducted in Kuwait but the information is locked up in reports which are not accessible to scientists. Our investigation concentrated on the taxonomic composition, diversity and quantitative estimates of macrozoobenthos during winter in Kuwait's marine environment.

Material and methods

Samples for the study were collected during 5–19 December 2004 from 17 stations, out of which 14 stations were located in the sublittoral zone (from 2 to 20 m depths), and 3 stations were located in the littoral zone. Sublittoral samples were collected from three sections: near Failaka Island, in Kuwait Bay, off Kuwait Bay and near Bubiyan Island (stations 2–5; 6–9; 1; 10–13 and 17, respectively; Fig. 1). Littoral samples were collected from three sites: station 14 in Kuwait Bay, in the vicinity of the Kuwait Institute for Scientific Research in Shuwaikh; station 16 in the littoral zone off the Mariculture and Fisheries Department (MFD) at Ras Salmiyah, and station 15 was located about 75 km to the south of Kuwait city, at Ras-Al-Zor, which is close to the border with Saudi Arabia.

Samples of sublittoral macrozoobenthos were collected with a Van Veen grab sampler with capturing area of 0.05 m^2, and littoral samples with a bottom dredge with an opening of 0.09 m^2. For some stations, oceanographic variables such as the seawater temperature of near-bottom layer, salinity, dissolved oxygen (DO) concentration, pH and turbidity were measured (Table 1). At each station, 2 samples were obtained, washed through a sieve of 0.5 mm mesh size and fixed with 4% formaldehyde. In the laboratory, benthic organisms were sorted, identified to species level when possible and counted. At station 17 one qualitative sample was taken, and at littoral stations samples of large organisms were additionally collected. Results obtained from qualitative sample processing were added to the list of species encountered for the sampled area, but were not used in the analysis of biodiversity.

In assessing macrozoobenthos diversity, the biodiversity indices of Shannon-Weiner (Shannon and Weaver 1963) and Simpson (Simpson, 1949) (H` and 1-λ`, respectively), as well as Margaleff index (D) (Margalef 1958) for species richness were used. Dominance was assessed by means of Simpson index (λ`) (Simpson 1949), and evenness by Pielou index (J`) (Pielou 1966).

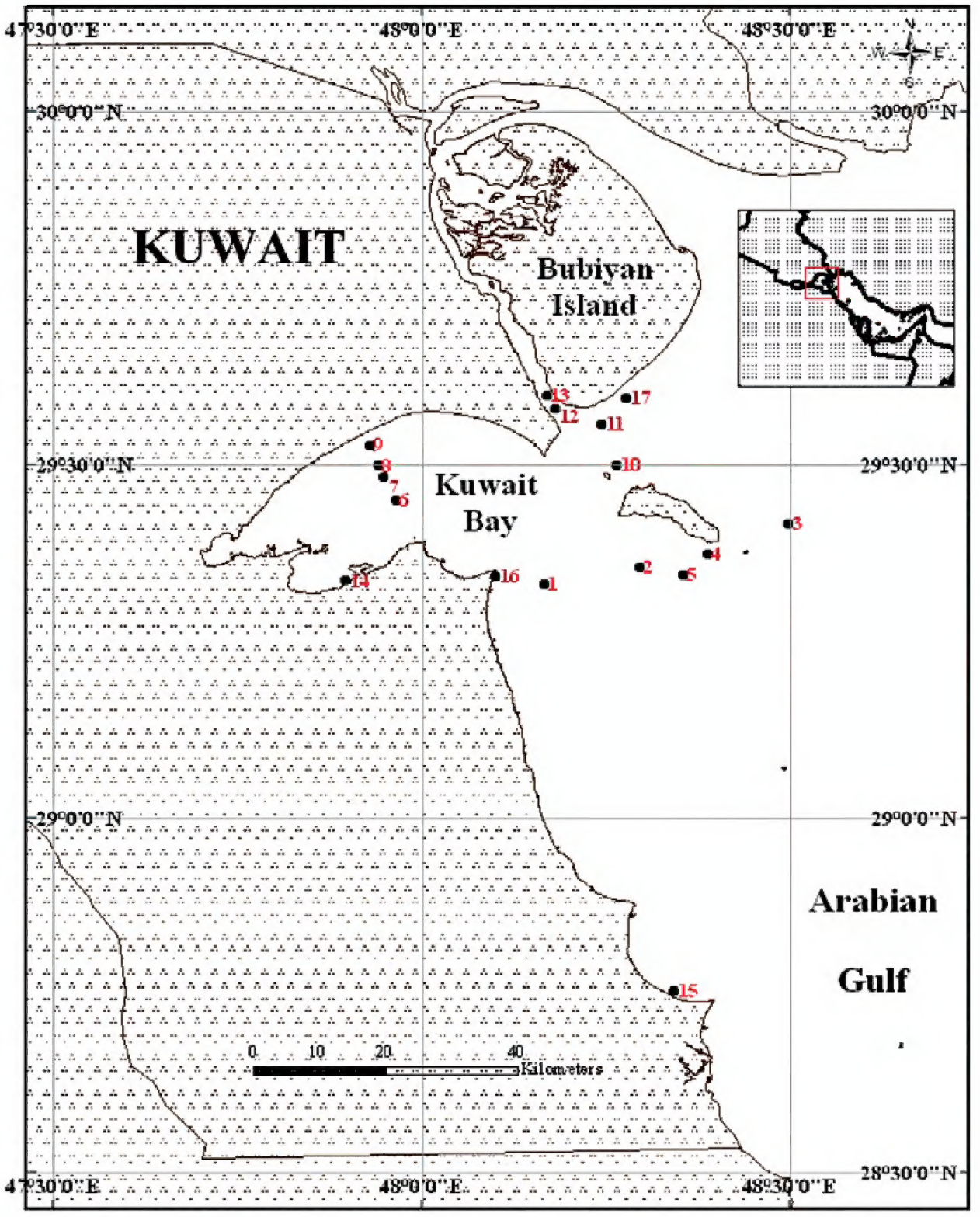

Figure 1. Location of the benthic stations sampled during 3–18 December 2004.

Results and discussion

Description of the study area

Kuwait's waters are shallow and its northern waters (off Bubiyan Island) are influenced by the discharges from Shatt Al-Arab River and Shatt Al-Basrah Channel. Kuwait Bay is relatively vast and shallow (about 12 m deep). Seawater salinity (41.38 PSU) and turbidity (10.44 mg/l) are high. The bottom substrate of the Bay is mainly composed of silt or silty clay. During our survey we encountered sediments smelling of hydrogen sulphide. Sediments in the central part of the Bay contain a large fraction of urchin

Table 1. Sampled stations and oceanographic variables measured at each station during December 2004 in Kuwait's marine environment.

Station No.	Transects	Coordinates	Depth, m	Bottom grab area sampled, m^2	Salinity, PSU	Temp., °C	DO, mg/l	pH	Turbidity, mg/l
1	Failaka	29°19.59'N 48°10.04'E	20	0.1	41.31	18.97	1.46	8.16	6.31
2		29 21.26'N 48°17.52'E	3	0.1	40.66	14.62	9.96	8.27	3.59
3		29°25.02'N 48°29.59'E	14	0.1	40.5	16.94	8.54	8.24	3.32
4		29°22.31'N 48°23.20'E	3	0.1	39.41	14.32	10.19	8.3	2.77
5		29°20.44'N 48°21.25'E	5	0.1	40.54	14.34	9.79	8.28	3.16
6	Kuwait Bay	29°27.00'N 47°58.00'E	12	0.15	41.38	16.86	8.05	8.16	10.44
7		29°29.02'N 47°57.01'E	7	0.1					
8		29°30.00'N 47°56.03'E	3	0.05					
9		29°31.44'N 47°55.51'E	2	0.1					
10	Bubiyan	29°30.00'N 48°16.00'E	5	0.1					
11		29°32.88'N 48°14.47'E	4	0.1					
12		29°34.51'N 48°11.00'E	5	0.15					
13		29°35.58'N 48°10.15'E	7	0.1	35.26	13.77	8.68	8.12	43.66
17		29°35.43'N 48°16.42'E	3	qualitative					
14	Intertidal	29°20.13'N 47°53.51'E	intertidal	0.18					
15	Intertidal	28°45.25'N 48°20.36'E	intertidal	0.18					
16	Intertidal	29°20.37'N 48°06.05'E	intertidal	0.18					

spines and shells debris. Bottom ground at the littoral station 14 is muddy-silt with a strong smell of hydrogen sulphide, as it is under considerable anthropogenic load owing to municipal sewage discharge.

The waters off Bubiyan are highly turbid (43.66 mg/l) and has lower salinity (35.26 PSU) than the rest of Kuwait's waters. The sea bed is predominantly silty, with sandy patches in the immediate vicinity of the Island.

Samples collected from the deeper station (station 1, 20 m depth) displayed lower concentration of dissoved oxygen (1.46 mg/l), and lower turbidity (3.83 mg/l) than in Kuwait Bay and near Bubiyan Island. At the southern littoral station (station 15) off the city of Al-Zor, the seawater transparency was the highest for the examined area, with nearby coral reefs. Strong tides affect the littoral stations 14 and 15, especially station 15. Station 16 is located between piers and therefore is relatively sheltered from wave activity.

Species composition and abundance of macrozoobenthos

Nearly 270 species, which represent 10 phyla of macrozoobenthos were recorded from the collected samples (Table 2). The most diverse groups were Polychaeta (83 species), Gastropoda (60 species), Bivalvia (57 species) and Crustacea (38 species). Lower number of species (Fig. 2) were encountered for Echinodermata (8 species), Cnidaria (4 species), Sipunculida (3 species) and Echiurida (2 species). Tentaculata and Hemichordata were represented with one species each. Organisms attributed to Nemertini, Turbellaria, Oligochaeta, Pantopoda and Brachiopoda were not identified to species level.

The bottom fauna displayed high taxonomic diversity, however, only 12 species were characteristic of the area (present in 25–50 % of stations): for polychaetes *Nephtys tulearensis, Sternaspis scutata, Paraprionospio pinnata, Sigambra tentaculata* and *Cossura* sp.; for crustaceans *Ampelisca* sp., *Iphinoe* sp. and ***Gnathia* sp.**, molluscs *Tornatina incospicua, Retusa* sp., *Chrysallida* sp., and *Tesseracme quadrapicalis.*

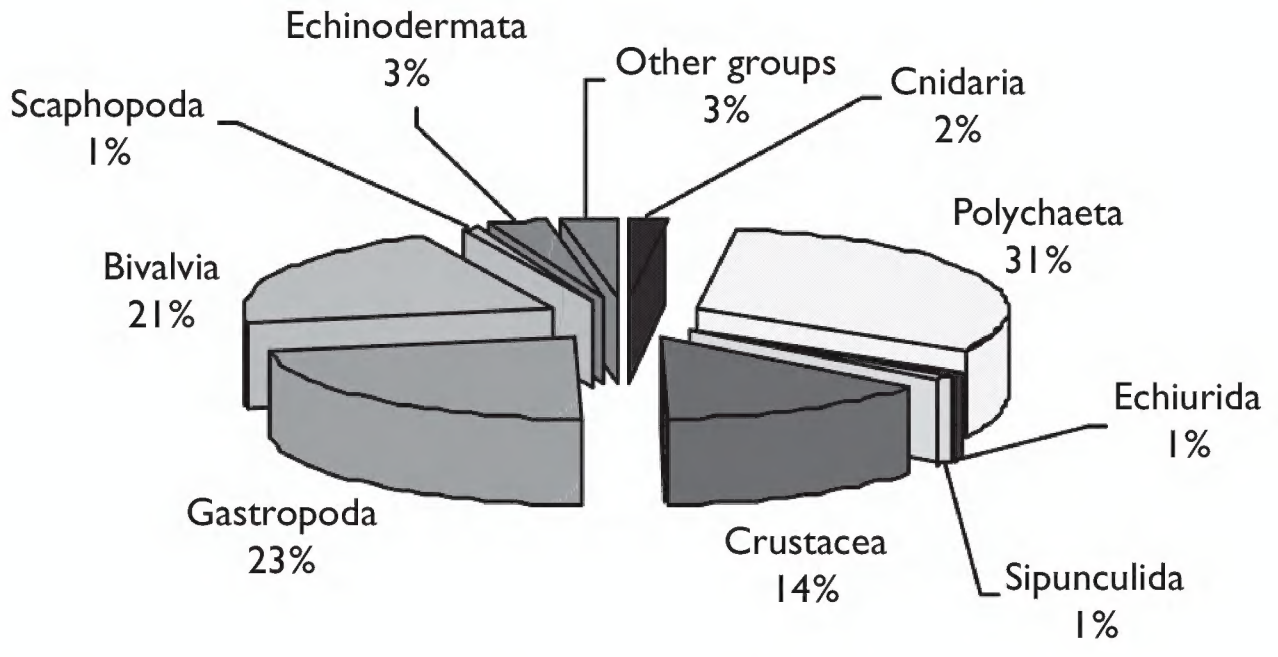

Figure 2. The percentage composition of species number of the different taxonomic groups.

Table 2. The taxonomic composition and the abundance (ind./m^2) of macrozoobenthic species at each sampled station (* found in the qualitative samples; **j.** refers to juvenile stage).

Species	Station																
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
CNIDARIA																	
Hydrozoa															6		
Anthozoa																	
Actiniaria g. sp. 1			30							30							
Actiniaria g. sp. 2										10							
Actiniaria g. sp. 3		10									10						
Actiniaria g. sp. 4												7					
PLATHELMINTES (Turbellaria)		10		10												50	
NEMERTINI	20	30			10						10						
ANNELIDES																	
Polychaeta																	
Aglaophamus sp.	10					7			10								
Amage sp.			110							10							
Ampharetidae g. sp.			10														
Amphicteis sp.			10														
Ancistrosyllis sp.			10							20							
Aricidea sp.	10							20	20								
Bhawania goodei			10			7				20			10				*
Brada mamillata				40						10							
Branchiomma cingulata																*	
Capitella capitata				10													
Capitella sp.					80												
Capitellidae g. sp.		10															
Capitomastus sp.	10																
Chaetopterus sp.								20									

Species	Station																
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Cirratulus sp.					10												
Cirrophorus harpagoneus												20					
Cirrophorus sp.		30															
Cossura sp.		10			20	20		120	30	10							
Diopatra neapolitana			10							40							
Diplocirrus glaucus			30														
Dodecaceria sp.					20					40							
Dorvillea sp.								40									
Eteone (*Mysta*) *ornata*				40													
Euclymene annandalei										10							
Euclymene insecta										20							
Euclymene sp.			20										10				
Eunice indica				80													
Eunice laticeps										40							
Exogone sp.										10							
Flabelligera diplochaitos				10													
Glycera rouxii			20			13				30							
Glycera tridactyla															61		
Glycera unicornis										30							
Glycinde sp.		20															
Goniada sp.									20								
Harmothoe dictyophora												13					
Harmothoe minuta			10														
Harmothoe sp.						7				10							
Hesionidae g. sp.						20											
Heteromastus filiformis	20																
Hydroides heteroceros															6		
Lanice conchilega	20																

Species	Station																
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Laonice cirrata	10		10														
Leonnates indicus			10		10												
Levinsenia sp.			30														
Loimia medusa			20							10							
Lumbrineris heteropoda																6	
Lumbrineris latreilli			10		20												
Magelona cornuta	20	10	10		10												
Maldane cristata										10							
Maldane sarsi			10														
Maldanidae g. sp.	10							20				7					
Melinnopsis sp.																	*
Micronephtys sp.										10							
Micronephtys sphaerocirrata	10																
Nephtys tulearensis		10			20				10	10			30				*
Nereis pelagica						7				10							
Ninoe pulchra		10															
Notomastus latericeus																44	
Onuphis sp.				10													
Ophelina acuminata										10		27					
Orbiniella sp.	10				10												
Paraonis sp.					20					10							
Paraprionospio pinnata	40	10	10	60	80					10	10						
Parheteromastus tenuis				40						10							
Pectinaria antipoda		10															
Pherusa (*Stylaroides*) *plumosa*										20							
Prionospio cirrifera								80	70				50				
Protodorvillea sp.					10											339	

Species	Station																
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Rhodine sp.			10														
Sabellidae g. sp.									100	120							
Schistomeringos incerta																50	
Scoletoma impatiens																439	
Scoloplos chevalieri				50									30				
Scoloplos sp.			50														
Sigambra tentaculata	20		10		60	7		20	30								
Sphaerosyllis sp.					10												
Spionidae g. sp.														11	6	100	
Spirobranchus tetraceros																*	
Sternaspis scutata			30	120	40					10	10	7					
Syllidae g. sp.									10								
Tauberia (?) sp.													10				
Terebellidae g. sp.						7											
Terebellides aff. *ypsilon*										30							
Terebellides sp.			40	10													
Tharyx multifilis				10	10												
Tharyx sp.			10														
Trichobranchus sp.			20														
Typosyllis cornuta									10								
Oligochaeta				120								7		56			
ECHIURIDA																	
Analassorhynchus branchiohinchus	10																
Listriolobus aff. *bulbocaudatus*						7											
SIPUNCULIDA																	
Phascolion convestitum																50	

Species	Station																
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Phascolion sp.	30																
Phascolion valdiviae var. *sumatrense*					10	20	20			20							
ARTHROPODA																	
Pantopoda										10							
Crustacea																	
Ampelisca sp.	20	10	40		30				10	150	30	7					
Ampithoe sp.																*	
Apanthura sandalensis													30				
Athanus sp.						7				10	10						
Balanus sp.			10											11			
Bodotria sp.			10														
Callianassa sp.												20	160				
Campylaspis sp.				10													
Cheiriphotis sp.										20		7					
Corophium sp.																*	
Cumella sp.				50											6		
Cumopsis sp.						7									11		
Cyclaspis sp.				10						30	10		10				
Cyclopoida g. sp.						7											
Cymadusa sp.																100	
Diogenes sp.										20		553					
Eocuma affine										20							
Eocuma sp.		10			50					10	20						*
Ericthonius sp.										20							
Gastrosaccus sp.															17		
Gnathia sp.		10	40	40	20				20			13				50	
Grapsidae g. sp.			20														

Species	Station																
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Ilyoplax sp.						7											
Iphinoe maeotica					10												
Iphinoe sp.	10	30	10		30	13	30		20								
Isopoda g. sp.			10						10		10				6		
Maiidae g. sp.			10														
Melita sp.					10	27	20				20						
Microphotis blachei			10														
Periculodes aequimanus			30														
Periculodes sp.	20	10			20											50	
Platyischnopus herdmani															22		
Raphidopus sp.						7											
Raphidopus sp.(megalopa)										10							
Siphonoecetes sp.												13					
Tylodiplax sp.								40									
Urothoe sp.													10			44	
Xanthidae sp.	10		10			7											
Urothoe grimaldii															17		
MOLLUSCA																	
Gastropoda																	
Action sp.			10														
Architectonica sp.										10							
Architectonicidae g. sp.	20					13	180										
Atys pellyi											10						
Atys sp. (*cylindrica*?)						7	10										
Bittium sp.														17	11		
Bulla ampulla															*		
Caecum sp.																350	
Cellana rota			10														

Species	Station																
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Cerithiidae sp.														122			
Cerithiopsis sp.																44	
Cerithium caeruleum															*		
Chrysallida sp.							30	260		10					11		
Chrysallida sp. (j.)											20						
Conus sp.					20												
Costellaria daedala	40				10				10								
Costellaria diaconalis												13					
Costellaria sp.						7				10	10	7					
Costellariidae g. sp.										10							
Cronia konkanensis																6	
Cylichna sp.	10						10	20			30						
Cymatium sp.															*		
Cyprea lamarckii															*		
Diodora rueppellii																*	
Ellobium sp.			10								10						
Ethminolia degregorii								20									
Euchelus asper															*		
Gastropoda g. sp. 1												13					
Gibberula sp.					10					10							
Haminoea vitrea								20									
Heliacus (*Torinista*) sp.	10	20									10						
Hypermastus sp.									20								
Leucotina gratiosa								20									
Melanella sp.	10																
Monilea chiliarches								20									
Monodonta nebulosa															*		
Nassarius emilyae															*		

Species	Station																
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Nassarius marmoreus																*	
Nassarius sp.	30					7	10										
Odostomia eutropia		10				7		20								44	
Odostomia sp.														6			
Omalogyra japonica																50	
Omalogyra sp.													20				
Pseudonoba sp.									450								
Pyramidellidae g. sp.				40	10								20			50	
Rapana venoza												7					
Retusa sp.		10				20	10	20			10					50	
Rhinoclavis kochi														94			
Rissoina sp.																50	
Siphonaria belcheri																*	
Splendrillia sp.							10										
Syrnola aclis		10															
Syrnola brunnea								20									
Syrnola sp.												7			6		
Terebra sp.	10																
Terebridae g. sp.	10																
Thais lacera																*	
Tornatina inconspicua		10				7		880	180						6	144	
Tornatina persiana						7											
Tornatina sp.					10												
Tricolia sp.								20									
Trochus erithreus																*	
Trochus fultoni															*		
Umbonium vestiarum															55		
Vanicoro sp.															*	*	

Species	Station																
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Bivalvia																	
Acar abdita															*		
Acar plicata															*		
Amphilepida faba (j.)								40		10							
Amphilepida sp. (j.)																250	
Anadara sp. 1 (j.)										30							
Anadara sp. 2 (j.)													10			50	*
Arca sp. (j.)										10							
Barbatia decussata															*		
Barbatia sp. (j.)												*					
Bassina calophylla															*		
Bivalvia g. sp. 1 (j.)	10						10					20	10			50	
Bivalvia g. sp. 2 (j.)		10	10	10		7						7				50	
Carditella sp.				10												44	
Cardites sp.										*							
Chama sp.															*		
Cheiriphotis sp.										20		7					
Corbula sp.				20						20							
Corbula sulculosa	40			10								40					
Corbula taitensis						33											
Curvimysella sp.												*					
Cymadusa sp.																11	
Didimacar tenebrica (j.)						7											
Donax sp.															6		
Dosinia sp. 1 (j.)		10	10				10								6	72	*
Dosinia sp. 2 (j.)									*								
Dosinia sp. 3 (j.)								*							*		
Ervilia sp. (j.)							10										

Species	Station																
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Glycymeris pectunculus															*		
Gregariella sp. (j.)																50	
Hiatula ruppelliana															*		
Kellia sp.												7					
Lithophaga robusta															*		
Loripes lucinalis (j.)																150	
Mactra lilacea												7					
Mactrinula sp.			10														
Malvifundus normalis															*		
Marikellia sp.																	*
Musculista senhousia												7					
Nucula consentanea							10			10							
Nuculoma layardii (j.)	30										20					244	
Ostrea sp. (j.)												66					
Paphia textile															*		
Paphia sp.																222	
Pinctada nigra															*		
Pinna muricata															*		
Syndosmya sp.				20													
Tachycardium assimile															*		
Tachycardium rubicundum															*		
Tellina donacina	10															9822	
Tellina methoria															*		
Tellina valtonis (j.)	20																
Tellina vernalis		10		10		7											
Tellina sp. 1				10													
Tellina sp. 2 (j.)															6	4544	
Theora cadabra (j.)					20				50		30						

Species	Station																
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Timoclea sp.1 (j.)	10															672	
Timoclea sp.2 (j.)			80							30							
Yoldia tropica (j.)	10																
Scaphopoda																	
Cadulus euloides																50	
Tesseracme quadrapicalis	10	10				7	60		10		30						
BRACHIOPODA												*					
TENTACULATA (Phoronidea)																	
Phoronis sp.	30			40	10	40											*
ECHINODERMATA																	
Amphipholis squamata (j.)				40								120					
Amphioplus (*Lymanella*) sp.					20					30							
Amphiura aff. *fasciata*			30	10						20							*
Diadema setosum																*	
Echinometra mathaei															*		
Macrophiothrix sp.					20	13		60								94	
Ohshimella ehrenbergi										10							
Temnopleurus toreumaticus						13											
HEMICHORDATA (Enteropneusta)																	
Saccoglossus sp.										10	10						
CHORDATA (Cephalochordata)																	
Branchiostoma sp.																167	

Sublittoral (subtidal zone)

The number of species found at stations situated in the sublittoral zone varied between 14 and 46, with an average of 30 species. Maximum number of species per station was registered at station 3 off Failaka Island (depth 2 m; salinity of 40.5 PSU; turbidity of 3.32 mg/l) and minimum at station 13 in Khor Al-Sabiyah off Bubiyan Island (depth 7m; salinity of 35.26 PSU; turbidity of 43.66 mg/l). The abundance of macrozoobenthos varied in the range of 340–1800 ind./m^2, with an average of 795 ind./m^2. In general, the sublittoral bottom grounds in the studied area are composed of silts. The ratio between the abundances of the different taxonomic groups reliably shows how the benthic organisms distribute on the silty beds (Fig. 3a). Most abundant are polychaetes, gastropods and crustaceans. Only at the station positioned at a sandy patch (5 m depth), where crustaceans, bivalved molluscs and echinoderms prevailed, the ratio was slightly different (Fig. 3b). Maximum numbers of macrozoobenthos was registered at station 8

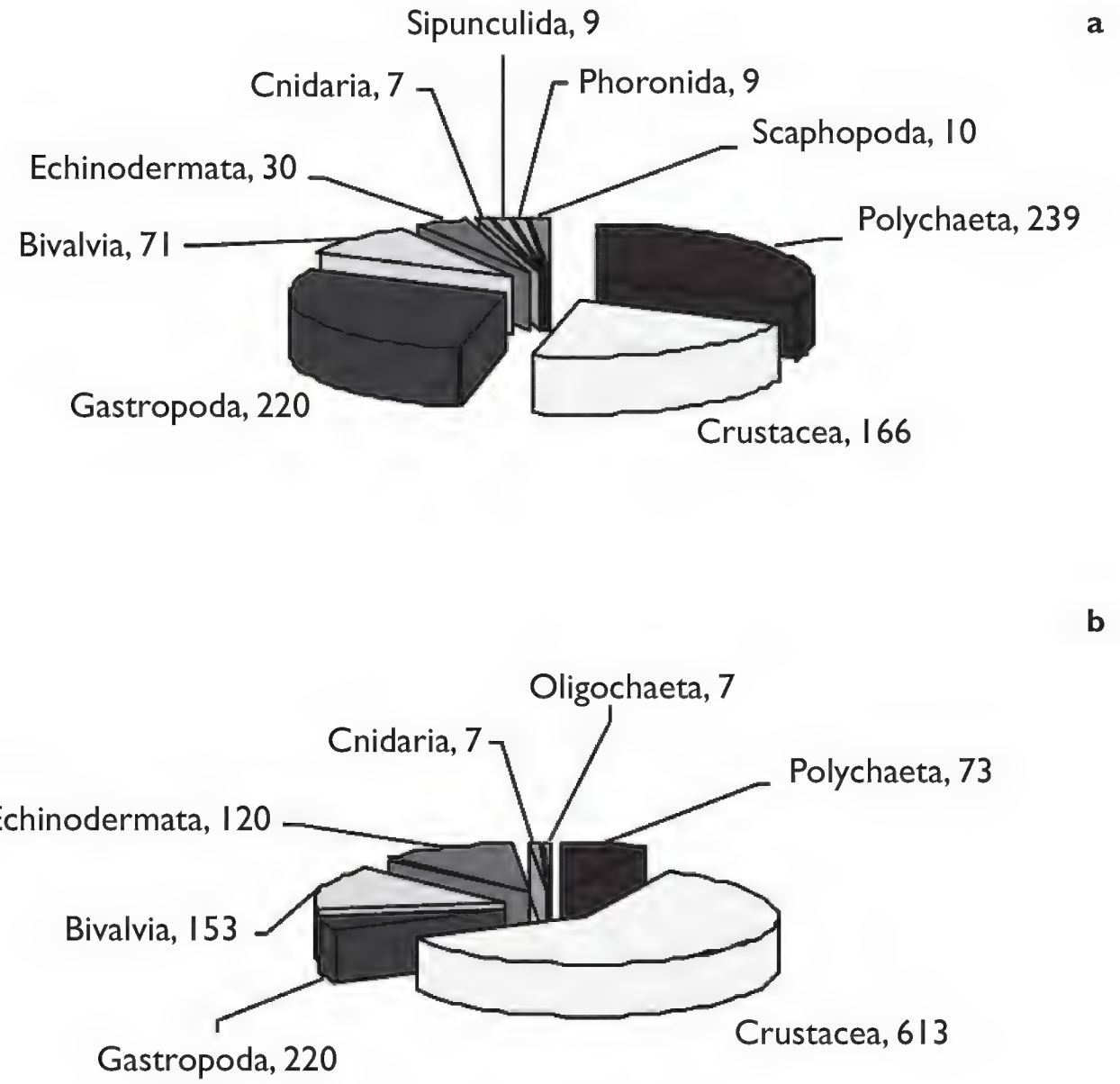

Figure 3. The abundance (ind/m^2) of different taxonomic groups of macrozoobenthos in the sublittoral zone: **a** Average distribution and **b** Distribution at station 12 in Khor Al-Sabiyah.

(3 m depth) in Kuwait Bay; small gastropods, *Tornatina inconspicua* and *Chrysallida* sp. contributed 50 and 14%, respectively, to the total abundance of benthic organisms.

Quantitative characteristics of macrozoobenthos differed among Failaka, Bubiyan and Kuwait Bay. In Kuwait Bay, the average abundance of benthic organisms was greater and the number of species were lower than near Failaka and Bubiyan Islands. The polychaete *Magelona cornuta*, crustaceans *Periculodes* sp., *Eocuma* sp., and *Cyclaspis* sp. were absent from the sampled Kuwait Bay stations. The percentage composition of the abundances of the different taxonomic groups inhabiting the Bay was different than that of the other sampled areas. The overwhelming majority in Kuwait Bay were bivalves (62%), followed by polychaetes (20%) and crustaceans (7%). Polychaetes and crustaceans prevailed at the other two areas of Bubiyan and Failaka islands (Fig. 4).

Analysis of macrozoobenthos distribution in relation to sampled station depth has revealed several interesting tendencies. In the examined depth range of 2–20 m, the abundance of macrozoobenthos decreased with increasing depth while the number of registered species increased (Fig. 5). Therefore, in analyzing species diversity indices for the above three areas the depth factor was taken into consideration (Table 3).

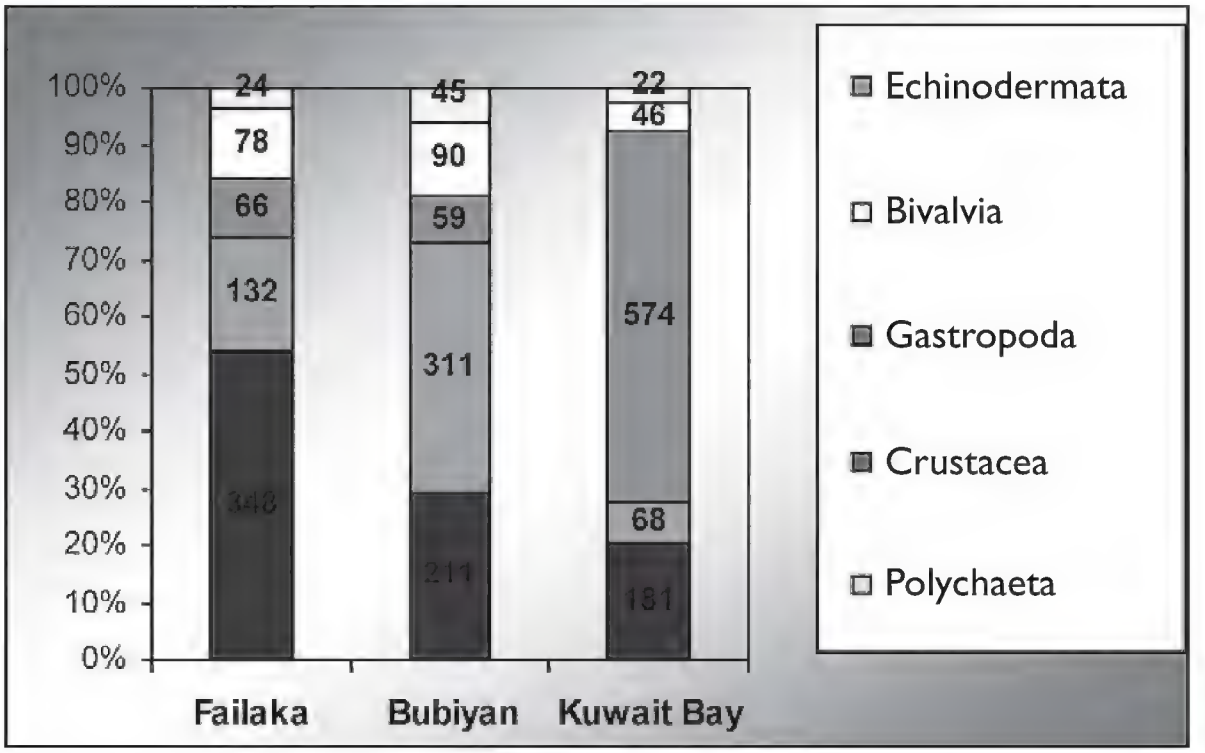

Figure 4. Percentage composition of the abundance of the main taxonomic groups in the sublittoral zone of the three sampled areas of Kuwait Bay, Bubiyan Island and Failaka Island.

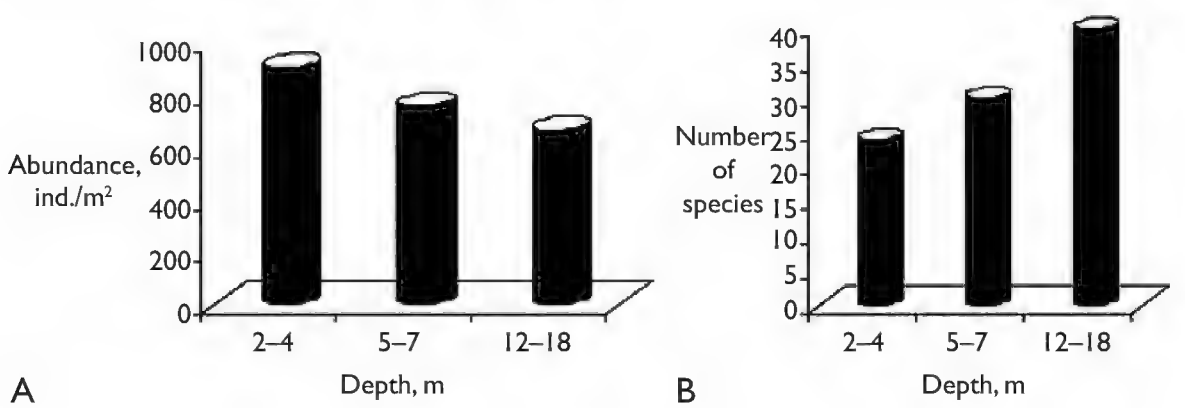

Figure 5. Changes in the abundance **A** and the number of species **B** in relevance with depth.

Table 3. The estimates obtained using Margalef index for species richness, Shannon-Wiener and Simpson indices for the diversity, Simpson index for the dominance and Pielou index for evenness (D, H`, l-λ`, λ`, and J`, respectively).

Station No.	Depth, m	S	N	Indices					
				D	H` (log_e)	H` (log_2)	1 - λ	λ	J`
1	20	36	620	5.443	3.445	4.970	0.965	0.035	0.961
2	3	26	340	4.289	3.154	4.550	0.954	0.046	0.968
3	14	46	950	6.563	3.525	5.086	0.960	0.040	0.921
4	3	31	960	4.369	3.057	4.410	0.939	0.061	0.890
5	5	35	760	5.126	3.285	4.740	0.952	0.048	0.924
6	12	35	406	5.661	3.367	4.857	0.960	0.040	0.947
7	7	15	430	2.309	2.083	3.006	0.788	0.212	0.769
8	3	21	1800	2.668	2.000	2.885	0.730	0.270	0.657
9	2	20	1090	2.717	2.108	3.042	0.784	0.216	0.704
10	5	57	1190	7.908	3.686	5.318	0.961	0.039	0.912
11	4	22	350	3.585	2.981	4.300	0.946	0.054	0.964
12	5	27	1029	3.748	1.963	2.833	0.689	0.311	0.596
13	7	14	410	2.161	2.127	3.068	0.810	0.190	0.806
14	inter-tidal	7	317	1.042	1.499	2.163	0.729	0.271	0.771
15	inter-tidal	17	259	2.879	2.424	3.497	0.877	0.123	0.856
16	inter-tidal	37	18430	3.665	1.686	2.432	0.652	0.348	0.467

S – total number of species.

N – total number of individuals (abundance, ind./m^2).

Species richness (D) and diversity (H') were highest (5.158 ± 0.812; 3.293 ± 1.528; 2.39 ± 0.64) in Kuwait Bay (Fig. 6). In the area near Failaka Island Pielou index (J') also yielded very high estimates (0.933 ± 0.028) approximating 1, which indicates high evenness level of the community. For Kuwait Bay, the corresponding estimates decreased to (0.769 ± 0.125) (Fig. 7a). Dominance index (λ') fluctuated from 0.03 to 0.28, the maximum was registered at station 8 (Kuwait Bay), where about half of the total macrozoobenthos abundance was due to the abundance of the small gastropod *Tornatina incospicua*. In general, the level of dominance was high (0.184 ± 0.98) in the benthic community of Kuwait Bay and very low (0.046 ± 0.009) near Failaka Island (Fig. 7b) that conforms with the statement that the higher the dominance, the less biodiversity in the area. Thus, the obtained results of the study suggest that the benthic community in Kuwait Bay is less diverse than that off Failaka Island.

For stations sampled near Bubiyan Island, all the studied indices varied in a broader range. The obtained averages point out that, based on the entire set of measured biodiversity parameters, benthic community of this area should be regarded as intermediate between the communities of Failaka Island and Kuwait Bay (Fig. 8).

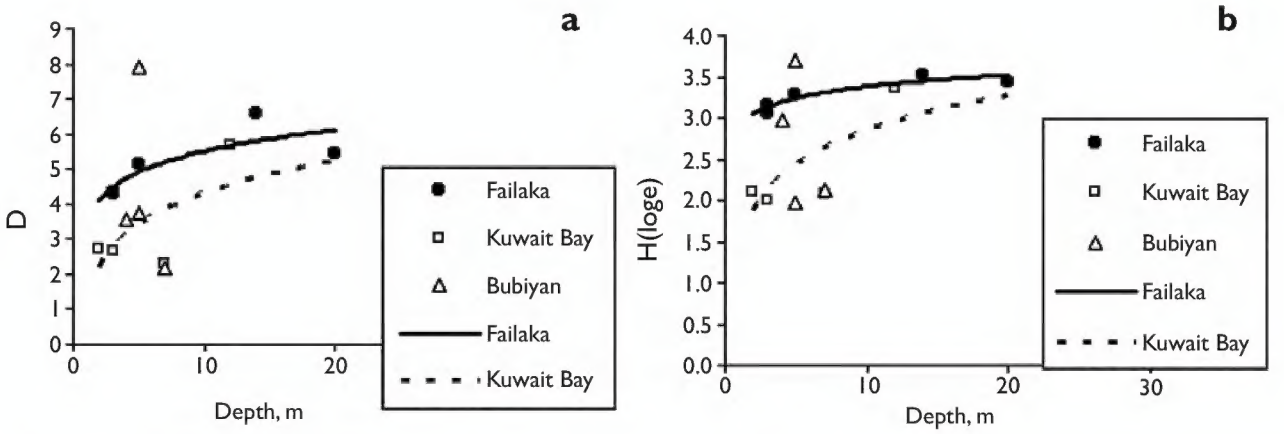

Figure 6. The variation in Margalef and Shannon-Wiener indices (D and H`$\log_e$, respectively, denoted as **a** and **b**, respectively) evaluated for the three examined areas (Failaka, Kuwait Bay and Bubiyan).

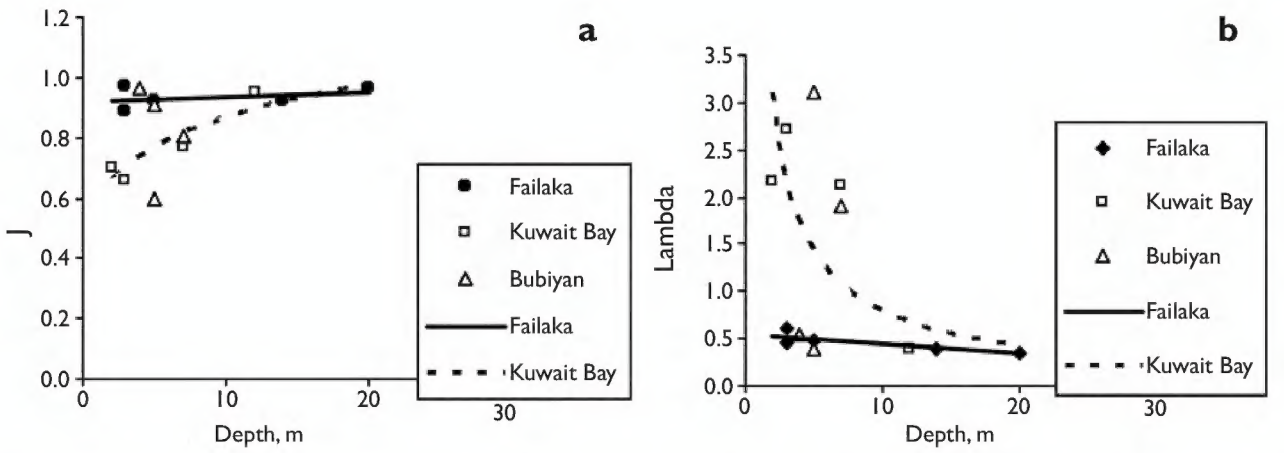

Figure 7. The variation in **a** Pielou index of evenness (J`) and **b** Simpson index of dominance (λ`) for the three sampled areas of Failaka, Kuwait Bay and Bubiyan.

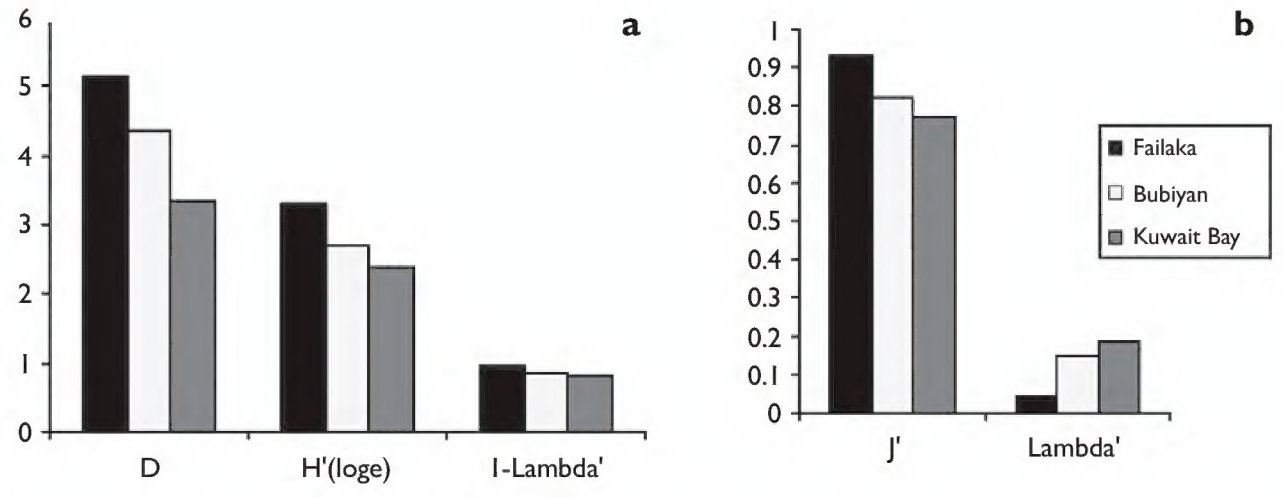

Figure 8. Averages of **a** the indices of diversity by Margalef, Shannon-Wiener and Simpson (D, H`$\log_e$ and l-λ`, respectively), and **b** Pielou index of evenness and Simpson index of dominance (J` and λ`, respectively) for the benthic community in the three studied localities.

Littoral (intertidal zone)

Abundance of macrozoobenthos substantially differed among stations. Station 16 (MFD/Ras Al-Salmiyah) displayed the largest diversity (38 species) and highest abun-

dance (nearly 18,000 ind./m^2); most abundant are the polychaete *Lumbrineris impatiens*, and the gastropod *Caecum* sp., lancets (*Branchiostoma* sp.), small crustaceans, and juvenile bivalved molluscs of several species. It is noteworthy that the total macrozoobenthos abundance at station 16 is more than 75% higher than at the other stations owing to the high juvenile abundance of two bivalved molluscs of the genus *Tellina* (*Tellina donacina* and *Tellina* sp.). These larval or juvenile forms were encountered in the collected benthic samples, probably soon after the larvae had settled on the bottom substrate. The settling larvae were about 0.3 mm in size; the majority of larvae in the collected samples were of 1 mm size. The unusually high abundance of macrozoobenthos at station 16, was probably due to its position in an area with less wave actions, unlike stations 14 and 15.

A total of 18 species of macrozoobenthos were found at station 15 (Al-Zor), with a total abundance of 260 ind./m^2. Most numerous were the polychaete *Glycera tridactyla*, the gastropod *Umbonium vestiarium* and small crustaceans of 6 species.

The least diversity (7 species) was registered at station 14 (KISR/Shuwaikh). The gastropod *Cerithidae* sp. (38% of the total abundance), oligochaetes (18%) and large nematodes prevailed. These organisms have well adapted to oxygen deficient substrate. Their presence in the absence of crustaceans and the extraordinary strong smell of hydrogen sulphide indicate anoxic conditions in the bottom sediment.

Though the obtained data are insufficient to provide for a detailed analysis of macrozoobenthos diversity in the littoral zone, they allow us to conclude that it is not as large as in the sublittoral zone. Comparison between the three stations shows that in Kuwait Bay the species richness and diversity both in the littoral and sublittoral zones are the least. Probably, this could be due to special oceanographic conditions as well as pollution impact from sewage and industrial discharges into the Bay (Al-Yamani et al. 2001).

Comparing the abundance of macrozoobenthos in the Arabian Gulf and in some other seas (Table 4), it is interesting to note that the abundance of bottom-dwelling organisms in silty biotope of the Arabian Gulf is superior to the Aegean, Mediterranean and Red seas but second to the Adriatic Sea.

Conclusions

The main findings of the study is summarized below:

Table 4. The average abundance of macrozoobenthos (ind./m^2) in different seas including the Arabian Gulf (according to Kisseleva 1968)

Biotope	Sea				
	Aegean Sea	Southern Adriatic	Eastern Mediterranean	Red Sea	Arabian Gulf This study
Silt	30	1020	15	283	795
Silty sand	200	1490	-	218	-

A total of 270 species of macrozoobenthos and representatives of higher taxonomic groups belonging to 10 phyla have been identified from Kuwait's marine environemnt. Species number is largest in polychaetes, gastropods and bivalved molluscs. High taxonomic diversity and the absence of mass forms are characteristic of the bottom fauna.

The abundance of macrozoobenthos varied from 260 to 18,400 ind./m^2. At stations with 2 to 20 m depths, the average abundance of macrozoobenthos is 795 ind./m^2. The groups prevailing in the sublittoral zone are polychaetes, gastropods and crustaceans (32, 29 and 22%, respectively).

Generally, Kuwait macrozoobenthos has high species diversity and low dominance level though biodiversity estimates may markedly differ depending upon the locality. Compared with other locations under the study, Kuwait Bay harbours less diverse benthic community.

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